# SEE Bulletin

Developing Tomorrow's Space Technologies Today

NASA's Space Environment and Effects Program

*Fall 1996 Issue*


## Comments/Suggestions

The SEE Program Office actively solicits the following SEE related:

- Web sites
- Experiments
- Facilities
- Publications
- Conferences

for use on the SEE Homepage Web site.

If you have any comments/ suggestions about the homepage and its content, please contact Billy Kauffman at:


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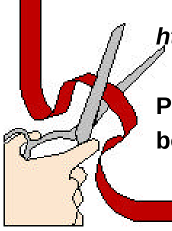
**The SEE Program website address has changed to:**

***http://see.msfc.nasa.gov***



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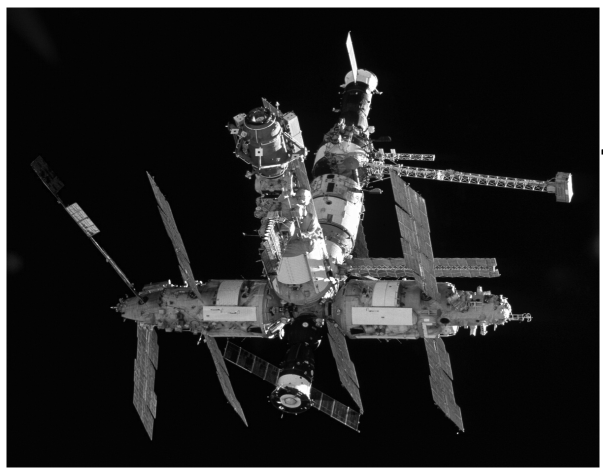

As a first step in the joint cooperation of Europe, Russia, Japan, and the United States in building the International Space Station (ISS), a series of docking missions are being conducted with the Mir Space Station and the Space Shuttle. One of the major purposes of these missions is to gather information on environmental and operational conditions on-board Mir and to apply this information to the ISS.

One activity that is a part of this program is the acquisition and analysis of photographic and video imagery data of the Mir from the Shuttle. This data is acquired by the astronaut crew using on-board photographic and video equipment during the rendezvous and mated operations with the Mir. The imagery is then processed, screened, and analyzed in the Image Science and Analysis Group of the Earth Science Branch at the Johnson Space Center in Houston, Texas and RSC-Energia, Kaliningrad, Russia. These analyses include both qualitative and quantitative assessments of external deposition and contamination, surface degradation, unanticipated solar array motion, micrometeoroid and orbital debris strikes, and configuration verification.

The current Mir station consists of seven modules: Base Block, Kvant, Kvant-2, Kristall, Spektr, Priroda, and an Orbiter Docking Module. The first module, Base Block, was launched in February 1986, with successive modules launched until the station assembly was completed in May 1996. Although the specific configuration of the Mir has changed over time, and a variety of modifications and repairs have been made to the external surfaces, there is, nonetheless, a fascinating record of long-duration exposure of the Mir to the space environment. This is especially significant since the actual on-orbit life of these modules has far exceeded their expected service life.

In general, the record of photographic documentation of the Mir since the launch of the first module has been sporadic, but the amount and quality of photo and video equipment on the Shuttle, as well as the ability of the Shuttle to perform fly-arounds of the Mir, has allowed a detailed survey of the Mir to be performed. Recently-launched modules, such as Spektr and the Docking Module, have been surveyed with little on-orbit time, which forms a good baseline from which future degradation can be compared. During the most recent Shuttle docking mission (STS-79), the Priroda module and the Cooperative Solar Array on the Kvant module have been photographed for the first time.

Photography (35mm, 70mm, and digital) is used to provide high resolution detail of the Mir. During the five missions performed to date, over 20 instances of surface

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## Development of a Computer-Based Space Environment Effects- Spacecraft Material Design Tool

*Dr. Edward Silverman, TRW Space & Electronics Group*

The NASA Space Environments & Effects (SEE) program has funded a task to develop a computer-based space environment effects - material design tool that will predict the long-term performance of spacecraft materials and components exposed to the space environment. The approach of this task is to combine design guidelines governing the effects of the space environments on materials with the computational space environmental models integrated within the Environment WorkBench (EWB) space environment analysis tool.

EWB is a knowledge-based, desktop, integrated design tool for analyzing the effects of space environments, both ambient and self-generated, on space systems. This tool includes NASA-sanctioned environment models such as MSIS-86, IRI90, AP-8, AE-8, and IGRF-87, and a Brouwer orbit generator. Space environment effects models in EWB include plasma interactions, atomic oxygen erosion, surface contamination (including power system degradation effects), UV absorptivity, meteoroid and debris damage, thruster-induced contaminant fluxes, and others. EWB has been used in support of the International Space Station plasma contactor program to design, locate, and assess Station plasma contactor system effects.

As part of the current SEE program effort, EWB is being modified to include a material properties database consisting of design performance properties (e.g., solar absorptance, thermal emittance, AO reactivities, time-dependent outgassing rates and species) of commonly used spacecraft materials (e.g., polymers, composites, coatings, thermal control systems, and metals). These properties are being compiled from “Space Environment Effects on Spacecraft: LEO Materials Selection Guide,” which contains flight experiment data from both short term Shuttle missions as well as longer duration LDEF and Solar Maximum missions.

EWB is also being modified to include several space environment effects-materials interactions models that will determine the performance of these materials. These models include atomic oxygen erosion of materials, UV effects on thermal-optical properties, and surface contaminant deposition including effects on solar absorptivity and solar array power degradation.

The effectiveness of EWB is being demonstrated by modeling of contamination effects on current spacecraft designs. Contamination analysis results are being used to select vent locations to minimize contamination fluxes to sensors, to evaluate vent outgassing, thruster plumes, and surface outgassing on very sensitive payloads, to locate sensors and star trackers at low plume density regions, and to minimize high contaminant depositions on battery radiators. In addition, a recent TRW study (Brent and Cottrell et al., “Modeling of Spacecraft Using a Modified Version of MOLFLUX and Comparison with a Continuous Flux Model”, SPIE’s 1996 International Symposium, August 1996) compared on-orbit contamination deposition analysis predictions of EWB to those of the conventional MOLFLUX contamination model for EOS-PM spacecraft sensor payloads.

A major difference between computation methods used by MOLFLUX and by EWB is that MOLFLUX computes view-factors using TRASYS. EWB uses an internal subroutine to define spacecraft geometry and only computes view-factors between the centroids of surfaces. EWB also allows only one bounce for molecular transport. Another difference is that EWB allows solar arrays and sensors to track the sun or objects and averages contaminant deposition over changing spacecraft geometry needed to accommodate this tracking. Only a “nominal” geometry is used for the MOLFLUX analysis, which introduces minor errors. In EWB the effect of surface temperature on outgassing rates and sticking coefficients is modeled by the user adjusting those values. Finally, EWB requires less time to develop a contamination model, which is critical in effecting design modifications early in the conceptual design phase of a spacecraft program.

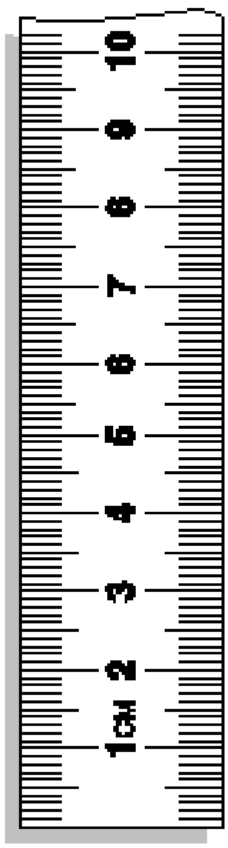
A comparison of EWB and MOLFLUX hydrocarbon deposition predictions for various EOS payload apertures (see table below), shows good agreement, especially considering the discrepancies between the two analytical methods. In fact, variations in predicted depositions are influenced more by differences in input data, such as outgassing rates and spacecraft geometry, than by differences in analytical methods used by the two codes. Clearly, MOLFLUX and EWB are predicting similar molecular contamination flux rates and consistent deposition data onto these sensitive aperture surfaces.

| Hydrocarbon Depositions Predicted by MOLFLUX and EWB (depositions in mg/ft$^2$) | | |
|---|---|---|
| Aperture | MOLFLUX | EWB |
| CERES-1 | 0.594 | 0.500 |
| CERES-2 | 0.467 | 0.430 |
| MHS | 0.197 | 0.034 |
| AMSU-A1 | 0.381 | 0.430 |
| AMSU-A2 | 0.019 | 0.010 |
| AIRS | 0.002 | 0.010 |
| MODIS | 0.041 | 0.063 |

Future SEE program efforts will include expanding the EWB materials database, developing temperature-dependent outgassing rates and surface deposition rates, and creating a materials performance - engineering requirements compliance matrix that will allow designers to evaluate and select materials for a specific spacecraft application and space environment. This will enable designers to perform “What if...” scenarios and engineering tradeoff studies, leading to cost-effective material solutions and optimum design features for specific subsystem requirements.

## A New Approach to Space Radiation Effects Measurements
### *Direct measurement of Linear Energy Transfer (LET) Values*

*E.G. Stassinopoulos, NASA/Goddard Space Flight Center*
*P.J. McNulty, Clemson University*



Evaluation of Single Event Effects performance of integrated circuits in the space environment has been a complex, multistep process, starting with the in-space measurement of a spectrum of ionizing particle energy, charge and mass. From these parameters, particle identification and correlating a Linear Energy Transfer (LET) spectrum can be derived. This measured LET spectrum is used to calculate the Single Event Effects performance of specific circuits with known Single Event Effects cross-sections. A new approach has been developed which uses integrated circuit technology to better represent the nature of the devices under investigation, and provide a direct measurement of LET.

This alternate choice is the use of solid state microdosimeters that measure the pulse-height spectra generated when energetic charged particles traverse p-n junctions having dimensions comparable to the sensitive volumes of modern microelectronics. The design is such that pulse amplitude is directly proportional to the particle LET. A compact small scale prototype of such a Pulse-Height Analysis (PHA) instrument has been developed by the Radiation Physics Office (RPO) of Goddard's Earth Sciences Directorate in cooperation with Clemson University.

The PHA detector is based on arrays of p-n junctions implemented in silicon. It uses advanced lithographic techniques developed by the microelectronic industry. The Detector records the pulse-height spectra from events at individual junctions having dimensions typical of SEU-sensitive structures of modern microelectronic devices. Each junction has associated with it a sensitive microvolume such that charge generated within that microvolume will contribute to the signal at the junction while charge generated outside will not. Proper design of the individual junctions can make the amount of energy deposited relatively insensitive to the direction of the incident particle. Prototypes using up to 2 million junctions have been demonstrated.

The purpose of flying such an instrument on board a satellite is to characterize the radiation environment in space in terms of risk and hazard to microelectronic or instruments, to optimize decisions regarding when to turn instruments on and off, to provide actual space data for improving algorithms for Single Event Effects predictions based on ground test measurements, or to assist in failure analysis during flight.

Some other benefits deriving from on-orbit measurements are: verification of models, correlation of events on a spacecraft to predictions, aiding in the analysis of spacecraft data, identifying possible causes of anomalies, failures or abnormal performance, enabling systems validation, characterizing solar proton events by deposition spectra behind different layers of shielding, assisting in post-flight performance evaluation of spacecraft components.

The PHA radiation monitor-microdosimeter has been designed to conform with current trends in spacecraft development. Thus, it's most appealing attributes are low cost, light weight, low power, small size, and minimal telemetry.

## Space Shuttle Imagery Survey of the MIR Space Station

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damage and discoloration have been identified using the handheld photography. These include: solar array damage on most modules, surface and thermal protection blanket damage and discoloration, some of which occurred in a four-month timeframe, flaking paint coating of a Spektr radiator, etc. The intensity, pattern, and location of noted discoloration is used by the technical community to determine whether its source can be attributed to outgassing, leaks, or atomic oxygen. In addition, over 50 potential micrometeoroid/orbital debris strikes have been identified and measured, with size ranges up to 25 $cm^2$. Finally, this photography is being used by the operational community for EVA planning and to verify hardware and experiment installation.

Video acquired from the Orbiter payload bay cameras is primarily used to capture dynamic events. This includes measuring solar array motion, estimating the size and velocity of free-floating debris, and characterizing thruster plume dispersion angles. Video has also been used to verify the orientation of the Mir External Environment Panels (MEEP) after EVA installation.

The photographic and video data have confirmed the robust design and good condition of the Mir station. NASA, and the space external environments technical community, is fortunate that not only is on-orbit photography an excellent way to convey the excitement and drama of the space program to the public, it can also provide technical data to characterize and understand the on-orbit environment.

The MIR photo surveys and other risk mitigation experiment data will be available on the SEE website in the very near future.

*Coming in Winter 1997 Issue...*

· ***Optical Properties Monitor***

· ***ISSEC and AETD Updates***

· ***Technology Development Activities Update***

## Latest SEE Program Happenings

**Technology Development Activities**

· Contamination Control Engineering Design Guidelines for the Aerospace Community, produced by Alan Tribble of Rockwell, has been a tremendous success with the technical community.

· Several other activities are scheduled to be completed in the upcoming months. The Program Office is looking forward to integrating the results into the SEE community.

**Space Environments and Effects Program Display**

· The SEE Program Office had a display set up at the AIAA held September 24-26th in Huntsville. Response was very positive and they are looking forward to setting up the display at the AIAA in Reno from January 6-9th, 1997. The Program Office is working hard on having more technical publications available for distribution in the near future.

**AETD and ISSEC Status Updates**

· Approximately 30 SEE-related proposals were submitted in response to the NASA Research Announcement (NRA) for the Advanced Engineering Technology Development (AETD) program in July. These proposals are currently in the selection process, although the basic review has been completed.

· Proposals in response to the Cooperative Agreement Notice (CAN) for the International Space Station as an Engineering Center (ISSEC) are due October 15. These proposals should present new technologies using the International Space Station as a base of operations. Submission details are given at the Internet site:
http://issa-www.jsc.nasa.gov/ss/issec/issec.html.